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IS CHOICE ACCURACY RELATED TO INFORMATION SEARCH PATTERNS?

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SUMMARY

In this experiment the hypothesis was tested that changing information search patterns, that are observed when task complexity increases, can be explained by an adaptive response to the choice environment. Two factors were manipulated: task complexity (number of alternatives and number of dimensions) and type of task (a multidimensional task requiring a choice between apartments and a unidimensional task requiring a choice between shopping baskets). Forty subjects made choices by means of computerized information boards. The results showed effects of both complexity and type of task on the information search patterns. The lowest proportion of requested information and the most variable search pattern was observed for the 'apartments' task in the complex task condition. However, accuracy remained constant over all complexity conditions. Together the results suggest that under high task complexity levels subjects try to work smarter rather than harder. Top-down approaches, such as making use of prior knowledge, the structure of the task, and the kind of goal, allow them to maintain accuracy and to avoid the integration of large amounts of information.

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Is de juistheid van een keuze gerelateerd aan het informatiezoekpatroon?

J.H. Kerstholt

SAMENVATTING

Beslissers gaan anders met informatie om als de complexiteit van het beslissingsprobleem toeneemt. In twee experimenten werd de hypothese getoetst dat deze veranderingen verklaard kunnen worden door een adaptieve reactie op de taakomgeving. Er werden twee factoren gemanipuleerd: taak complexiteit (aantal alternatieven en aantal attributen) en het type taak (een multidimensionele taak waarin een keuze gemaakt moet worden tussen een aantal appartementen en een unidimensionele taak waarin een mand met boodschappen moet worden gekozen). Veertig proefpersonen maakten keuzes met behulp van gecomputeriseerde informatieborden. Uit de resultaten blijkt dat zowel taakcomplexiteit als het type taak een effect heeft op het informatiezoekpatroon. Met name de proefpersonen die een appartement moesten kiezen in een complexe taakconditie gebruikten relatief weinig informatie en vertoonden het meest variabele zoekgedrag. In alle complexiteitscondities bleef echter de juistheid van het gekozen alternatief constant. Een plausibele verklaring voor de gevonden resultaten is dat de proefpersonen probeerden "slimmer" in plaats van "harder" te werken in complexe taakcondities. Met top-down benaderingen zoals het gebruiken van kennis, de structuur van de taak en het doel kunnen ze toch juiste beslissingen nemen en wordt de integratie van grote hoeveelheden informatie vermeden.

1 INTRODUCTION

Process tracing research aims to identify the cognitive processes that underlie decision making behaviour and to specify how various task and context variables affect the way people deal with decision problems (Einhorn, Kleinmuntz & Kleinmuntz, 1979; Payne, 1982). A recent review by Ford et al. (1989) revealed that the major part of this research used information boards as a technique to deduce the decision strategy that subjects employ to arrive at a decision. An information board depicts a matrix that specifies the potential alternatives (e.g. houses or cars) and the attributes, which are the characteristic aspects of the alternatives. Subjects are required to successively indicate combinations of one attribute and one alternative, which results in the associated values appearing on the screen. This process continues until they feel that enough information has been obtained to make a choice.

Subjects can request the available information in various ways. They can for example request all information or just a part of it, they can request the same or various amounts of information across alternatives and they can search for information alternative-wise or attribute-wise. A major assumption underlying the information board paradigm is that the patterns of information search behaviour reflect the decision strategies that the subjects have employed to solve a decision problem (Billings & Marcus, 1983; Svenson, 1979; Payne, 1976, 1982).

It is consistently found that information search patterns are highly affected by task complexity, which is usually defined by the number of alternatives and/or attributes (Billings & Marcus, 1983; Olshavski, 1979; Payne, 1976, 1982; Sundström, 1987; Westenberg & Koele, 1990). Generally, under high complexity levels depth of search decreases, i.e. subjects request less information, and search variability increases. These changes in information search pattern are interpreted as a shift from the employment of compensatory strategies to the employment of noncompensatory strategies. A compensatory strategy is characterized by the consideration of trade-offs, or the acknowledgement that low values on one attribute can be compensated by high values on another attribute. Noncompensatory decision strategies on the other hand are characterized by an interactive use of attribute values. This means that an alternative is rejected or maintained depending on the correspondence between a single attribute value and some subjective criterion.

Compensatory strategies are assumed to be the most complex and sophisticated decision rules, and are commonly used as a norm for the quality of a decision (Christensen-Szalanski, 1986). However, in spite of their incomplete information search patterns, noncompensatory rules do surprisingly well in terms of the decision outcome itself (Paquette & Kida, 1988; Payne, Bettman & Johnson, 1988). By means of simulations Payne et al. (1988) determined both the accuracy and the prerequisite effort of various decision rules while varying context and task variables such as time pressure and the dispersion of probabilities. In a gamble with a low degree of dispersion each outcome has about the same probability to occur (e.g. .30, .20, .22, and .28). In gambles with a high degree of dispersion on the other hand, some outcomes are far more likely to occur than

others (e.g. .68, .12, .05 and .15). The simulations showed that depending on the choice environment noncompensatory heuristic rules performed rather well. In the empirical part of their study subjects were required to make choices under time pressure and in various dispersion conditions and their performance was compared to the simulation outcomes. The results showed that to a large extent the subjects selected the rules that were indicated by the simulations as most efficient. Therefore, subjects took advantage of the characteristics of the choice environment in their decision making process such that accuracy was maintained at the lowest level of invested effort.

The tasks that are most often used in information board studies require choices between apartments or consumer goods (Ford et al., 1989). However, these choice tasks typically allow for top-down influences such as making use of high dispersion of attribute weights or the intercorrelations between attribute values (Bettman & Park, 1980; Huber, 1983; Johnson, 1987). When task complexity increases subjects may well seek to employ strategies that take advantage of the task structure (Klein, 1983). In this way, they can maintain accuracy but reduce the cognitive strain induced by the bottom-up integration of large amounts of information.

This suggestion was explored in two experiments in which we investigated the effect of task complexity and type of task on information search patterns and choice accuracy. In the first experiment a "conventional" task was used requiring a choice between apartments. Based on previous results we predicted that information search patterns would change with increasing complexity, but on the assumption that subjects try to maintain accuracy we also predicted that accuracy would remain constant over complexity conditions.

The most popular explanations for switches in information search patterns with increased complexity refer to limitations in processing capacity. However, when the use of a compensatory rule is not strictly necessary for accurate task performance, the use of a heuristic may be an adaptive response to task complexity, such that accuracy is maintained and processing effort saved. In order to discriminate between the explanation that subjects are forced to change strategy by capacity limitations and the explanation that subjects adaptively react to their choice environment, a second experiment was conducted. In this experiment subjects had to choose between shopping baskets, which contained groceries of differing costs. Since the attributes in the "baskets"-task were equally weighted and uncorrelated this task requires the employment of a compensatory rule for accurate task performance. Again, we predicted that subjects would maintain accuracy. However, since for accurate task performance a compensatory rule is required we predicted for this task that search patterns would not change over complexity conditions.

The results for both tasks can be compared more easily when the findings of the two experiments are presented simultaneously. In both experiments the same procedure and design were used. Therefore, in order to enhance understanding of the results we collapsed the data of both experiments and considered "type of task" as a between subjects factor.

2 METHOD

2.1 Subjects

40 students from the University of Utrecht participated in the experiment. Their mean age was 21.7 years ($\sigma = 1.5$ years) and they were paid Dfl.20,- for participation.

2.2 Material

Two different tasks were used which were both presented on a computerized information board. The first task required a choice between apartments. The apartments could be specified on maximally 8 attributes: rent (300, 600 or 900 Dutch guilders), size (2, 3 or 4 rooms), location (bad, moderate or good); distance to work (long, moderate, or short); distance to shops (long, moderate or short); noise level (high, moderate or low); garden or balcony (big, small or absent) and state of repair (good, reasonable or bad). The second task required a choice between shopping baskets, each of which contained up to 8 groceries. The groceries were indicated by single letters.
The alternatives (apartments or baskets) were specified in the columns and the attributes (apartment characteristics or groceries) in the rows of the information board matrix. For the "apartments"-task care was taken to avoid dominant alternatives, that is, alternatives that clearly stand out by having desirable values on all of their attributes. The values in the "baskets"-task were randomly assigned, and varied between 0 and 10.

2.3 Procedure

For both choice tasks subjects sat in front of a computerized information board. They could successively indicate a combination of an alternative and an attribute after which the corresponding value appeared in the appropriate matrix cell. All requested information remained visible until a choice was made. Subjects were instructed to request as much information as they needed to make an accurate choice. After each trial they indicated how confident they were that a correct choice was made and how difficult they found the choice problem on a 9-points scale.
Subjects in the "apartments"-condition carried out two additional tasks, which were needed for the calculation of the multi-attribute utility value of each apartment in the choice sets. First, they indicated the attractiveness of each attribute-level on a 7-points scale. Second, in order to get the weight of each attribute, subjects were asked to judge 81 apartments on attractiveness by giving them a score between 0 and 100. Each apartment was described on 8 attributes. Presenting all possible combinations of attribute levels would result in 3^8 judgements. In order to reduce this number a subset of these possibilities was

selected by means of a 3^4 fractional factorial design (Kirk, 1968). Before the judgement scores were given subjects were first asked to describe an apartment with the worst value levels (score 0) and an apartment with the best value levels (score 100). These combinations were written on cards and could be used as anchors in the judgement task.

2.4 Design

In order to manipulate the complexity of the choice task the number of attributes (4 or 8) and the number of alternatives (3 or 6) were varied. They were both manipulated as a within-subjects factor. To avoid sequence effects the order of task complexity conditions was balanced across subjects. Type of task was considered as a between-subjects factor.

3 RESULTS

As mentioned in the introduction, previous studies have consistently shown that task complexity affects the depth and the variability of information search. In the following section we first describe our results on these variables, followed by the effects of complexity and type of task on choice accuracy, the subjective difficulty scores and the confidence scores.
Figure 1 shows the effect of task complexity on depth of search (indexed by the proportion of requested information) for each task condition.

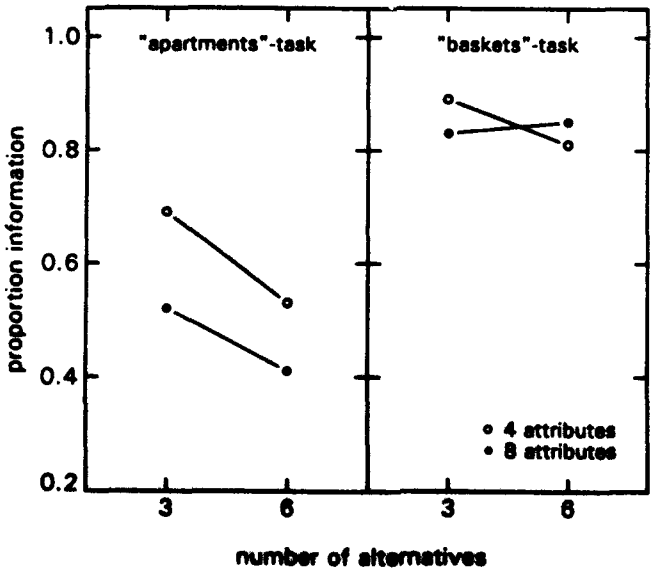

Fig. 1 Proportion of requested information for each complexity and each task condition.

An analysis of variance with one between subjects factor (type of task) and two within subjects factors (number of alternatives and number of attributes) was carried out over the proportions of information requested in each condition. The proportion of requested information significantly differed between task conditions, such that more information was requested in the "baskets"-task [$F(1,38)=73.42$; $p<0.0001$]. Both the number of alternatives and the number of attributes significantly affected the proportion of requested information [$F(1,38)=23.41$; $p<0.0001$ and $F(1,38)=24.26$; $p<0.0001$ respectively]. Furthermore, a significant interaction was observed between number of alternatives and number of attributes [$F(1,38)=6.20$; $p<0.05$]. However, both number of alternatives and number of attributes significantly interacted with the task condition [number of alternatives by task $F(1,38)=7.99$; $p<0.01$, number of attributes by task $F(1,38)=19.00$; $p<0.0001$].

In order to assess the differential effects of complexity in both tasks we carried out a separate analysis of variance for each task condition. In the "apartments"-task complexity significantly affected the proportion of requested information [number of alternatives: $F(1,19)=25.27$; $p<0.0001$, number of attributes: $F(1,19)=38.38$; $p<0.0001$]. In the "baskets"-task on the other hand, neither number of alternatives nor number of attributes affected the proportion requested information. This result shows that task complexity only reduces depth of search in the "apartments"-task and not in the "baskets"-task.

Figure 2 shows the variability of search, indexed by the mean standard deviation of the proportions of requested information units across alternatives, for each complexity and task condition.

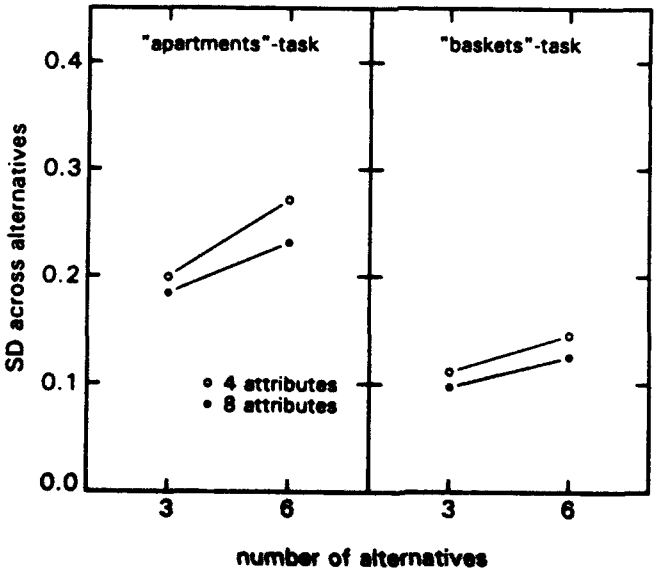

Fig. 2 Mean standard deviation of requested information units across alternatives for each complexity and task condition.

Again type of task significantly affected the variability of search [$F(1,38)=24.14$; $p<0.0001$]. In the "apartments" task the variability of search is greater than in the "baskets" task. Number of alternatives significantly affected the variability of search [$F(1,38)=11.19$; $p<0.005$]. As the number of alternatives increases, the variability of search increases as well. Note that within the information board paradigm variability of search is directly translated to the kind of strategy that is used, i.e. increases in the standard deviation across alternatives indicate the employment of noncompensatory strategies. The results show that both complexity (number of alternatives) and type of task affect the variability of search.

In addition to the information search patterns we were interested in the accuracy of the decision outcome. Only in the "baskets"-task an objectively "best" alternative could be defined. The prices of the groceries in the baskets were simply added and the least expensive basket was defined as the best alternative. A choice was considered accurate only when this most economical alternative was selected.

The quality of the alternatives in the "apartments"-task was deduced by applying a multi-attribute utility rule to each apartment in the choice set. To get the input for such a rule subjects had provided attractiveness scores, utilities, to each attribute level and judgment scores to 81 apartments. The weights of the attributes were deduced from linear regression analyses with the judgment scores as the dependent variable and the utilities of the attribute levels as the predictors. The mean adjusted squared multiple r over subjects was 0.64 ($\sigma=0.12$). The multi-attribute utilities for each apartment and for each subject were calculated by adding the weighted utility scores of each attribute. In contrast with the accuracy scores in the "baskets"-task we took the relative agreement between predicted and actual choices, because of the inherent error in the calculated overall utilities. This means that a small difference between the values of the chosen alternative and the most accurate one could be due to error rather than inferior task performance. Following Johnson and Payne (1985) we expressed agreement between actual choices and predicted linear choices by relating the utility of the chosen alternative to the overall evaluation of the best and the worst option:

$$\textit{relative agreement} = \frac{U_{choice} - U_{min}}{U_{max} - U_{min}}$$

A score of 1 implies that the alternative with the highest overall utility was chosen and a score of 0 that the alternative with the lowest multi-attribute utility was selected. Figure 3 shows the accuracy scores of both tasks under the different complexity conditions.

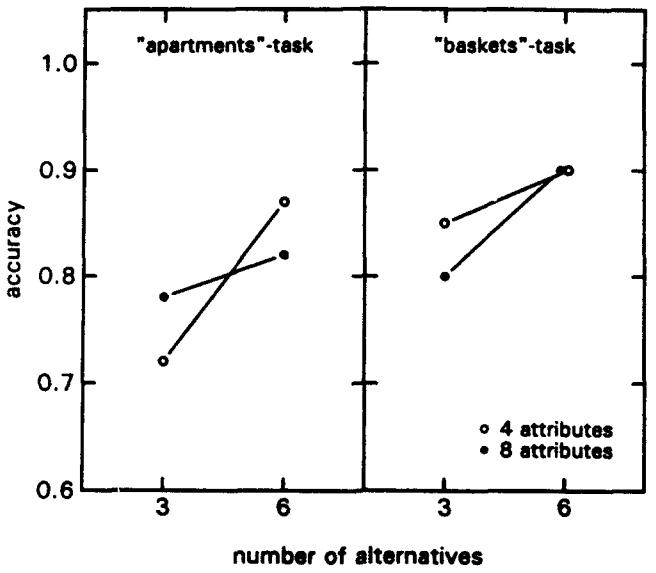

Fig. 3 Accuracy of the chosen alternatives for each complexity and task condition.

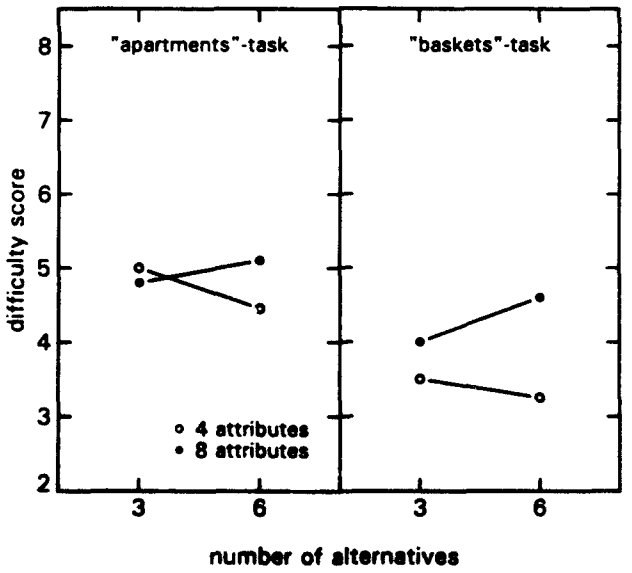

Fig. 4 Mean difficulty score for each complexity and task condition (9-points scale varying from very easy to very difficult).

Complexity did not affect the accuracy of the actual decision for both tasks. Even though the search patterns changed over task complexity conditions, subjects maintained a constant accuracy level.

Figure 4 shows the subjective difficulty scores. Type of task significantly affected the experienced difficulty [$F(1,38)=4.47$; $p<0.05$]. The "baskets"-task was considered less difficult than the "apartments"-task. Number of attributes had a marginal significant effect on the difficulty scores [$F(1,38)=3.65$; $p=0.06$]. However, rather than more difficult the choice problems became easier with an increased number of attributes.

Figure 5 shows the subjective confidence levels for each task complexity condition.

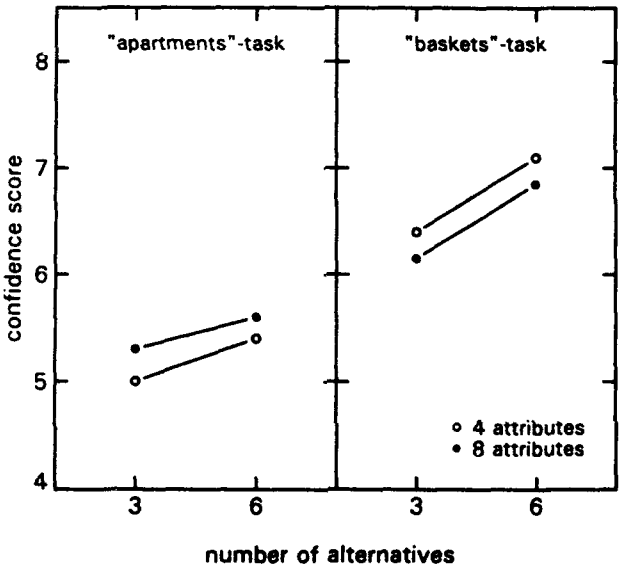

Fig. 5 Mean confidence score for each task and complexity condition (9-points scale varying from very unconfident to very confident).

Type of task significantly affected confidence in the chosen alternative [$F(1,38)=7.10$; $p<0.01$]. Subjects are more confident about their choices in the "baskets"-task than about their choices in the "apartments"-task. Furthermore, as the number of alternatives increased confidence scores increased as well [$F(1,38)=4.59$; $p<0.05$].

4 DISCUSSION

Our findings provide a clear answer to the central question of this paper: choice accuracy is not related to information search patterns. Whereas information search patterns changed over complexity conditions, subjects maintained a constant accuracy level.

As predicted from previous results, in the "apartments"-task depth of search decreased and the variability of search increased over task complexity conditions.

Since accuracy remained constant over complexity conditions this result suggests an influence of task structure on the possibility to overcome cognitive strain as task complexity increases. In process tracing studies a rather specific class of tasks is used such as choices between apartments or consumer products. By its structure, e.g. high dispersion of attribute weights, these tasks may have allowed for the application of heuristics. A popular interpretation for the switches in information search patterns under high complexity conditions are capacity limitations of the human information processing system. However, in the present experiment it was shown that even though information load remained constant over the task conditions, subjects only switched to heuristic search in the "apartments"-task. Therefore, rather than forced by capacity limitations subjects seem to react adaptively to their choice environment.
One plausible mechanism for the observed effects of task complexity on search patterns and accuracy level, is that subjects try to work "smarter" under high levels of task complexity, rather than just "harder" by integrating larger amounts of information. Under low information load conditions information can be integrated in a strict bottom-up way. Under high information load conditions on the other hand, a top-down approach helps to reduce the cognitive strain of integrating large amounts of information and to maintain accuracy. In the following we will illustrate three of such top-down approaches, i.e. making use of the structure of the task, prior knowledge and the kind of goal.

Type of task significantly affected all dependent variables. In the "baskets"-task depth of search was higher and search variability was lower than in the "apartments"-task. This result was predicted since the "baskets"-task was selected so as to ensure that a compensatory, linear rule would be normative for accurate task performance, i.e. all attributes should be equally weighted, and the attribute values were uncorrelated. For both task conditions accuracy remained constant over complexity conditions but search patterns were differentially affected. This supports the idea that subjects seek to maintain a fixed accuracy level, and use heuristics when it leads to equally efficient task performance, i.e. only in the "apartments"- task.

If subjects take their choice environment into account in selecting a decision strategy an important question is how they decide to decide (Payne, Bettman & Johnson, 1990). In the present tasks subjects did not need to explore the task structure in the experimental session, but were assumed to have prior knowledge on its structure. For the "apartments"-task they knew their evaluations of the attribute weights and of the attractiveness of the attribute values, since a "real-world" decision task was used in which prior knowledge and evaluations can be applied. Furthermore, for the "baskets"- task it is assumed that calculating the overall costs by adding the costs of the separate attributes, i.e. employing a linear rule, is quite familiar to the subjects. Subjects are likely to use their (strategic) knowledge of the relationship between the employment of decision rules in various choice environments and the accuracy of the outcome. However, the observed changes in information search patterns over task complexity

conditions suggest that the use of prior knowledge is more dominant in complex task environments.
The results showed that even though more information is requested in the "baskets"-task subjects rated the decision problem as less difficult than the "apartments"-task. A major difference between the tasks is the dimensionality of the decision problem. In order to determine the overall values subjects could simply add all prices in the "baskets"-task whereas they had to integrate different units in the "apartments"-task. Even though the subjects accurately dealt with this problem, they may for this reason have found the "apartments"-task more difficult.
Confidence levels were higher in the "baskets"-task than in the "apartments"-task, which may be explained by the familiarity of the task (Huber, 1989). In the "baskets"-task the decision rule is clearly linked to the outcome of the decision. Prices have to be added and the lowest overall price is unquestionably the best alternative. In that regard, confidence is mediated by knowledge of the relationship between a decision rule and accuracy of the outcome.

We predicted that the search pattern in the "baskets"-task would not change over complexity conditions. However, even though depth of search indeed remained constant, a higher search variability was observed when the number of alternatives increased.
This finding can be explained when the goal, selecting the best alternative, is taken into account. Whenever the added costs of an incompletely described alternative exceed the overall value of a completely described alternative, it can be dropped from the choice set. When more alternatives are available, the discrepancy between the proportions of requested information between alternatives for which all information is requested and the ones eliminated may be increased, resulting in higher search variability across alternatives. This explanation was tested by means of Monte Carlo simulations that provided the standard deviations of the proportion requested information across alternatives for each task complexity conditions. The results from these simulations indeed showed that the variability of search increased when the number of alternatives increased (3 alternatives: $\sigma = 0.12$; 6 alternatives: $\sigma = 0.18$). In agreement with our findings the standard deviation across alternatives marginally decreased with an increased number of attributes (4 attributes: $\sigma = 0.16$; 8 attributes: $\sigma = 0.13$).
Therefore, even in a task that intuitively requires knowledge of all information, subjects requested information selectively, within the constraints of reaching their goal, i.e. selecting the cheapest alternative.
Recent research indeed showed the differential effects of response mode on information search patterns. If the subjects are required to make judgments rather than choices information search is more elaborate (Billings & Scherer, 1988; Westenberg & Koele, 1990). Based on the present results we suggest that this effect is a rather adaptive reaction to the goal set for the subject.

To summarize: The present experiment clearly shows that information search patterns are not related to choice accuracy. Even though both task complexity

and type of task affect the information search pattern choice accuracy remained constant. It is suggested that in addition to the bottom-up integration of requested information and its related computational constraints, the utilisation of prior knowledge, the stated goal, and the task structure should be taken into consideration. More specifically, rather than increasing their effort in integrating all information, subjects may adaptively reduce cognitive strain by intensifying top-down processing in complex task conditions.

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In this experiment the hypothesis was tested that changing information search patterns, that are observed when task complexity increases, can be explained by an adaptive response to the choice environment. Two factors were manipulated: task complexity (number of alternatives and number of dimensions) and type of task (a multidimensional task requiring a choice between apartments and a unidimensional task requiring a choice between shopping baskets). Forty subjects made choices by means of computerized information boards. The results showed effects of both complexity and type of task on the information search patterns. The lowest proportion of requested information and the most variable search pattern was observed for the "apartments" task in the complex task condition. However, accuracy remained constant over all complexity conditions. Together the results suggest that under high task complexity levels subjects try to work smarter rather than harder. Top-down approaches, such as making use of prior knowledge, the structure of the task, and the kind of goal, allow them to maintain accuracy and to avoid the integration of large amounts of information.

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4, 5. Hoofd Wetenschappelijk Onderzoek KLu
6. { Hoofd Wetenschappelijk Onderzoek KM
   Plv. Hoofd Wetenschappelijk Onderzoek KM
7, 8, 9. Hoofd van het Wetensch. en Techn. Doc.- en Inform. Centrum voor de Krijgsmacht

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Extra exemplaren van dit rapport kunnen worden aangevraagd door tussenkomst van de HWOs of de DWOO.
